IX.   **DISTRESS AND SAFETY COMMUNICATIONS**

Proposed Rule § 25.143(f) is the same as § 25.142(b)(4), which applies to NVNG MSS. Motorola does not object to the proposed rule. Motorola notes that it is clear that, consistent with its decisions in the Little LEO Order, the Commission does not intend to require Big LEO MSS licensees to show specific methods of interconnection to route distress communications. As in the Little LEO context, MSS services "are not intended to replace existing international safety services and cannot be used in lieu of distress beacons, such as emergency locator transmitters or emergency position indicating radio beacons, that are required to be carried by international agreement or statute." Little LEO Order, 8 FCC Rcd. at 8458. Accordingly (as is also evident from the proposed language), the proposed rule would apply only for MSS stations that are used to comply with any of those requirements.

X.   **THE COMMISSION SHOULD IMPLEMENT AND REINFORCE THE PROPOSED MILESTONES**

Like the Commission's proposed financial qualification standards, the milestones contained in the NPRM are necessary to ensure that the LEO MSS spectrum does not lie fallow, and that the Commission's requirement of global service is satisfied. Motorola has two recommendations.

First, the Commission should restrictively define the types of actions that qualify as the beginning of construction for the purpose of the commencement of construction milestones. Otherwise, it would be too easy to circumvent these milestones by

claiming that they are satisfied by any step towards the commencement of construction, no matter how inconsequential and embryonic.

Second, the Commission should institute an additional milestone whereby licensees must establish, or arrange for the establishment and operation of, the ground segment infrastructure in countries representing at least 75% of the world's population and surface area within six years of the grant of the space segment license. As explained above, this milestone is necessary to ensure satisfaction of the Commission's proposed global service requirement, which might become ineffectual without the international ground segment infrastructure.

XI. OTHER LICENSING RULES

Motorola has three further recommendations with respect to the licensing rules set forth in proposed § 25.143.[48/]

First, the term "technically identical" as used in § 25.143 may be read as an unduly narrow restriction on the design of replacement satellites. Under a strict reading of the term, a functionally equivalent replacement satellite that achieves more efficient use of the spectrum may not be "technically identical" to its replaced satellite and thus may not fall within the blanket space station license. The Commission should avoid penalizing licensees seeking to improve the efficiency of their systems by imposing on them additional

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[48/]   Motorola fully supports the blanket licensing approach proposed by the Commission with respect to mobile transceivers and the Commission's policy in favor of international roaming. See NPRM ¶ 88-89.

regulatory burdens. Accordingly, the term "functionally equivalent" should be substituted for "technically identical."

Second, while compliance with the reporting requirements of § 25.143(e) would be relatively easy for a geostationary system, some of these reporting requirements could prove very cumbersome and/or inapposite for multi-satellite LEO systems. Motorola recommends elimination of § 25.143(e)(1)(iv), requiring a breakdown between domestic and transborder transmission, and information on unused capacity or capacity sold but not in service within the U.S.
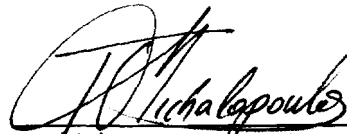
Third, with respect to the prohibition of § 25.143(g) on trafficking in MSS licenses, Motorola agrees that the Commission should preclude the trafficking in bare licenses. On the other hand, the Commission must allow the current group of applicants to finance their systems by offering both debt and equity participation. It is also important that the Commission recognize that its band sharing plan could be the subject of abuse if one of the CDMA licensees were to bolster up another CDMA licensee in order to prevent the FDMA/TDMA system from gaining access to the 3.1 MHz of spectrum held in reserve if only one CDMA system became operational. The Commission should make clear in its decision that such a practice would be unacceptable.

XII.   CONCLUSION

Motorola supports the proposals contained in the NPRM with the modifications and clarifications that it recommends herein, and urges the Commission to issue a Report and Order in this proceeding expeditiously.

Respectfully submitted,

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Dated: May 5, 1994

TECHNICAL APPENDIX

Part 1)   Uplink Out-of-Band Emissions Limits and Technical Sharing
          Criteria for the 1610-1626.5 MHz Band

Part 2)   Radio Astronomy Protection Criteria

UPLINK OUT-OF-BAND EMISSIONS LIMITS AND TECHNICAL SHARING CRITERIA FOR THE 1610-1626.5 MHZ BAND

1. SUMMARY

The out-of-band emissions rule found in Section 25.202(f) must be updated to reflect the operation of MSS and AMSS(R) systems under the band segmentation rules proposed in the FCC's Notice of Proposed Rule Making for the 1610 MHz to 1626.5 MHz band.

The proposed rules provide for the operation of wideband CDMA systems and narrowband TDMA/FDMA systems in adjacent segments of the band from 1610 MHz to 1626.5 MHz. The out-of-band emissions rules must provide reasonable protection to services and systems operating in this band from other MSS systems operating in the band. Further, the out-of-band emissions rules should recognize and be compatible with the very different signal characteristics of the two MSS technologies, so that neither technology bears an undue burden in complying with the rules.

The proposed amendment to Section 25.202 will establish an out-of-band emissions spectral mask for MSS earth stations operated in the 1610 MHz to 1626.5 MHz band. The proposed mask is based on fixed power levels and frequencies regardless of the transmission characteristics of the particular systems. The proposed mask will provide adequate protection for MSS and AMS(R)S systems operating in the 1610 MHz to 1626.5 MHz band as well as protection for services operating in adjacent frequency bands.

The proposed mask is compatible with existing power amplifier designs that have been developed for use in small portable cellular handsets of the type envisioned for use by MSS operators. It is compatible with existing power amplifiers that have been designed to support CDMA technology and existing power amplifiers that have been designed to support TDMA/FDMA technology.

2. EXISTING RULE 25.202 DOES NOT PROTECT THE UPLINK CHANNELS IN THE ADJACENT BAND SEGMENTS

The current rule in Section 25.202 specifies the out-of-band emissions in terms of PSD relative to total transmitter power at offset frequencies that are relative to the authorized bandwidth of the transmitter. This rule does not adequately account for the differences in transmitter characteristics when it is applied to a variety of system designs. Further, it does not account for the case of multiple carriers simultaneously sharing the same bandwidth, which is a characteristic of CDMA operation. As a result, the interference from CDMA MSS transmitters operated in accordance with Section 25.202 results in

harmful interference with the TDMA/FDMA systems in the adjacent band segment as described in the following analysis.

2.1 Uplink Interference Analysis

A CDMA mobile transmitter interferes with an TDMA/FDMA uplink channel when out-of-band emissions from that transmitter arrive in the satellite antenna beam that is servicing the TDMA/FDMA channel. This problem is exacerbated because a satellite antenna beam encompasses a large area on the earth's surface and many CDMA mobile transmitters may be included in that beam. The uplink interference analysis must, therefore, include the combined interference from an indeterminate number of CDMA mobile units. It must further consider the propagation conditions between the satellite and CDMA mobile units at different locations.

It is assumed in this uplink interference analysis that CDMA mobile transmitters are uniformly spread over the region from which they can interfere with a particular TDMA/FDMA satellite antenna beam. In addition, the mix of faded and unfaded CDMA propagation paths was varied to bound the interference situation. It was also assumed that the CDMA mobile transmitters operate in accordance with the out-of-band spectral limits currently contained in Section 25.202. A typical spectrum for a CDMA transmitter operating within these limits adjacent to the TDMA/FDMA band is illustrated in Figure 1.

Figure 2 is an idealized drawing of the coverage areas of several TDMA/FDMA satellite antenna beams. The center beam (labeled victim beam) is the beam which serves the uplink TDMA/FDMA channel under consideration. The area from which the victim beam is susceptible to interference is indicated by the shadowed area where the darker shadow indicates higher antenna gain. As shown in the figure, an antenna beam covers a larger area than its assigned service region because a practical antenna pattern cannot be made to roll-off infinitely fast. This is accounted for in the interference analysis with the simplifying assumption that any CDMA mobile transmitter in an adjoining beam contributes interference to the victim beam, but at a lower level than CDMA mobile transmitters in the area served by the victim beam.

Range to the victim satellite does not have a significant impact on the uplink interference because the entire region covered by a single antenna beam is essentially at the same range, so that the relative signal strength of the TDMA/FDMA and CDMA mobile transmitters is maintained over the link except when it is altered by differential fading.

The various CDMA mobile transmitters may have different out-of-band emissions levels in the TDMA/FDMA channel. This is particularly true for a

channelized CDMA system. These systems subdivide their allocated band segment into a number of frequency channels and operate a fraction of their subscriber links in each frequency channel.

ALL REQUIREMENTS ARE PFD LIMITS RELATIVE TO THE TOTAL TRANSMITTER POWER (WATTS / 4KHZ)

1ST PLATEAU ISOLATION (25 dB)

2ND PLATEAU ISOLATION (35 dB)

3rd PLATEAU (43 dBW/4 kHz)
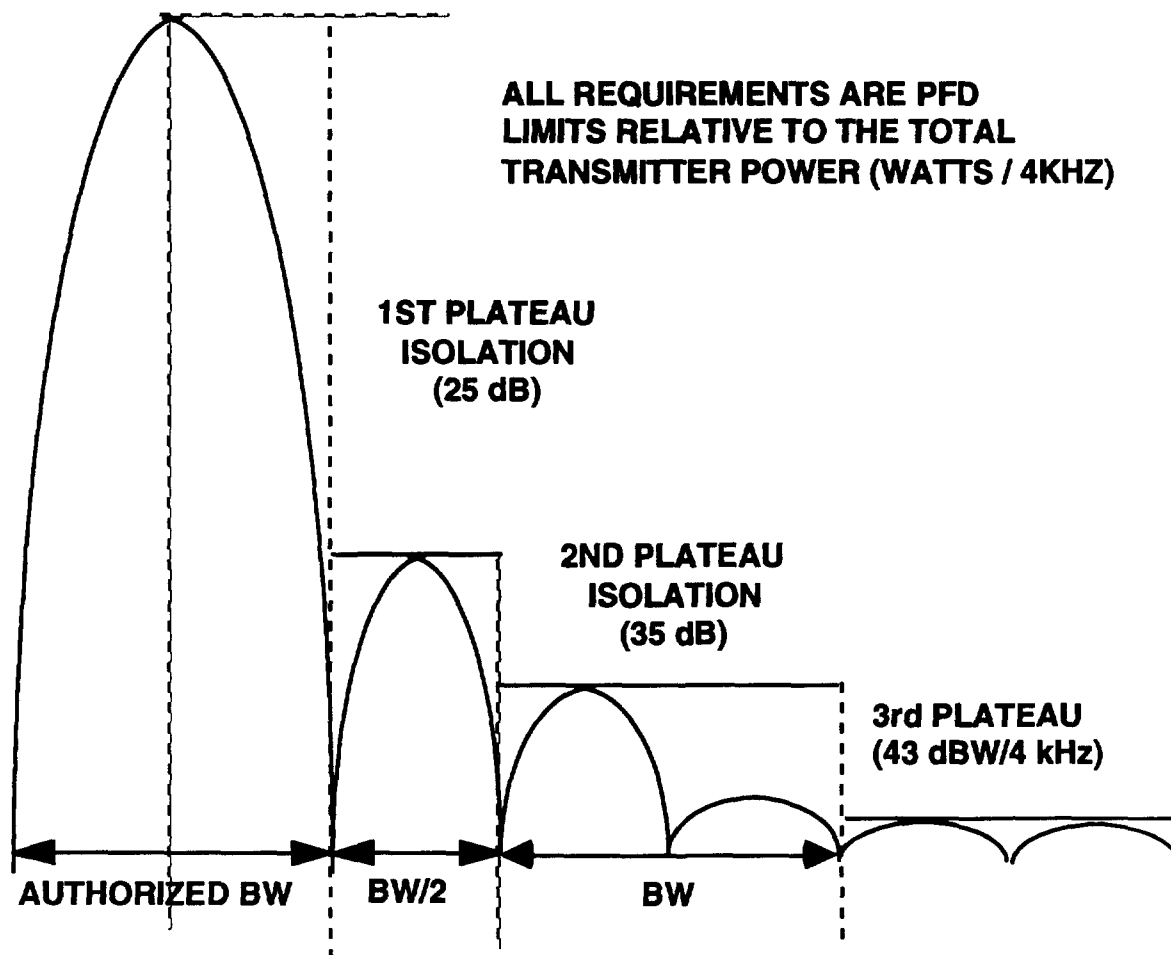
AUTHORIZED BW   **BW/2**   **BW**

Figure 1. Typical CDMA Spectrum and 25.202 PSD Mask

As Figure 1 illustrates, the out-of-band emission power generated by a CDMA mobile transmitter tends to decline as the frequency offset from the assigned channel increases. Thus, the interference from a CDMA mobile transmitter operating in a frequency channel immediately adjacent to the TDMA/FDMA band will tend to be greater than that received from a CDMA mobile transmitter operating in a channel farther removed from the TDMA/FDMA band. Nevertheless, the transmitters in the CDMA channels farther removed from the band edge will contribute some level of interference in the TDMA/FDMA band.
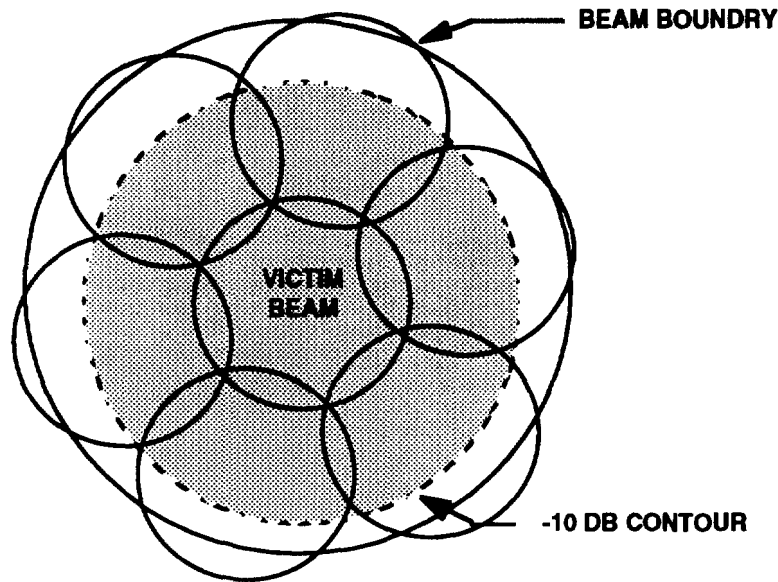
Page 3

Figure 2. Idealized Beam Interference Region

Figure 3 also shows that out-of-band emissions from one CDMA frequency channel are a source of interference in the other CDMA frequency channels in the band. The capacity of a CDMA system is primarily a function of its interference levels. Thus, it is expected that the designers of CDMA mobile transmitters will want to reduce their out-of-band emissions to protect their own channels and enhance their system capacity. This is certainly the case with power amplifiers for mobile units that Motorola has designed to operate with the terrestrial CDMA cellular system described in the TIA/EIA Interim Standard 95 (TIA/EIA IS-95).
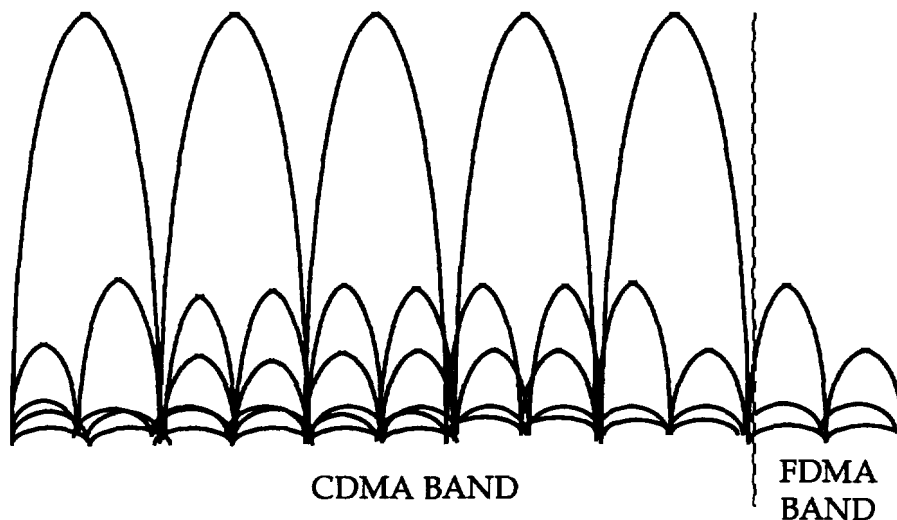

CDMA BAND   FDMA BAND

Figure 3. Typical Channelized CDMA Spectrum

A final simplifying assumption was made on the fading condition in the interfering channels. A fraction of the CDMA mobile units were assumed to be operating with a constant average excess path loss. The remaining CDMA mobile units were assumed to transmit on unfaded channels.

As mentioned previously, the range between the satellite and all of the transmitters that it can receive from the earth's surface is essentially a constant. Thus, except for differential fading and antenna gain, all of the transmitters experience the same path loss. Thus, to determine the relative carrier-to-interference level due to the CDMA mobile transmitters, it is only necessary to determine the ratio of the TDMA/FDMA unit effective radiated power and the combined effective radiated power of the CDMA mobile units after correcting for the propagation, antenna gain and out-of-band emissions differences. With all of these simplifying assumptions, the received signal to interference-plus-noise ratio at the satellite is given by the following expression.

$$\frac{Es}{No+Io} = \frac{P_{FDMA}\alpha}{B_n[No+Io_i+Po_xA_N\{[\partial_1+\partial_2+(b-2)\partial_w](1+\beta\eta)[v\varepsilon+(1-v)]\}]} \quad [1]$$

Where :

P_{FDMA} = The TDMA/FDMA unit EIRP

α = The fading loss on the TDMA/FDMA channel

Bn = The satellite receiver noise bandwidth

No = The satellite receiver thermal noise floor

Io_i = The internally generated interference power density

Po_x = The peak effective radiated PSD of a CDMA mobile unit

An = The number of CDMA mobile units in one antenna beam service area and one CDMA frequency channel

b = the number of CDMA frequency channels in the CDMA band

∂_1 = the first out-of-band isolation plateau at the TDMA/FDMA channel

∂_2 = the second out-of-band isolation plateau

∂_w = the final (wideband) out-of-band isolation plateau

β = the number of neighboring antenna beam service areas that contain interfering CDMA mobile units

η = the antenna gain isolation between the victim antenna beam and the neighboring beams

v = the fraction of CDMA mobile units that are operating on a faded propagation channel to the victim satellite

ε = the average fade level of a faded propagation channel

Table 1 provides the parameter values assumed for the uplink interference analysis.

TABLE 1
UPLINK INTERFERENCE ANALYSIS PARAMETERS FOR
REPRESENTATIVE CDMA AND TDMA/FDMA SYSTEMS

<u>PARAMETER</u>	<u>VALUE</u>
CDMA MOBILE UNIT:	
EIRP	0.05 dBWi
Channel Bandwidth	1.25 MHz
Peak Effective Radiated PSD (Po)	-24.9 dBWi/4 kHz
Out-of-Band Isolation (25.202)	
1st Plateau	25 dB
2nd Plateau	35 dB
Final Plateau Additional Isolation	43 dBW/4 kHz
FDMA SATELLITE:	
Thermal Noise Floor (No)	-201.6 dBW/Hz
Internal System Interference (Io)	-219.6 dBW/Hz
Noise Bandwidth	25 kHz
Neighboring Beam Antenna Gain Isolation	10 dB
FDMA MOBILE UNIT :	
PSD - EIRP	-3 dBWi/4 kHz
System and Propagation Parameters :	
Number of Adjacent antenna beam service areas	6
Number of CDMA channels/ CDMA band segment	9
Average fade level in a faded channel	10 dB

Table 2 contains the results of the uplink interference analysis. The loss in TDMA/FDMA link fade margin is given for various fading conditions as a function of the number of CDMA mobile units per antenna beam area per CDMA channel. If a 1 dB loss in link performance is defined as harmful interference, then clearly, the CDMA mobile units operating in accordance with Rule 25.202 (-25 dB 1st out-of-band emissions plateau) result in severe interference levels into the TDMA/FDMA system. Even if the out-of-band emissions limits are reduced by 10 dB so that the first plateau occurs at -35 dB, the interference is unacceptable for any reasonable number of CDMA users, except under the most optimum fading condition.

TABLE 2
CDMA UPLINK INTERFERENCE IMPACT ON THE TDMA/FDMA UPLINK LINK FADE MARGIN

Faded/Unfaded	0.00	0.00	0.33	0.33	0.67	0.67	1.00	1.00
1st Plateau Isolation	25.00	35.00	25.00	35.00	25.00	35.00	25.00	35.00
Users/Beam/CDMA Channel	Loss in Link Margin	Loss in Link Margin	Loss in Link Margin	Loss in Link Margin	Loss in Link Margin	Loss in Link Margin	Loss in Link Margin	Loss in Link Margin
10	4.27	0.67	3.36	0.48	2.22	0.28	0.67	0.07
20	6.38	1.25	5.24	0.91	3.69	0.55	1.25	0.14
30	7.79	1.77	6.54	1.31	4.78	0.79	1.77	0.21
40	8.86	2.22	7.54	1.67	5.65	1.03	2.22	0.28
50	9.71	2.84	8.36	2.00	6.38	1.25	2.64	0.35
60	10.43	3.02	9.04	2.31	7.00	1.46	3.02	0.42
70	11.04	3.36	9.63	2.60	7.54	1.67	3.36	0.48
80	11.58	3.69	10.15	2.87	8.03	1.86	3.69	0.55
90	12.05	3.99	10.62	3.12	8.46	2.05	3.99	0.61
100	12.48	4.27	11.04	3.36	8.86	2.22	4.27	0.67

These results would be substantially worse for wider band CDMA systems operating in accordance with Rule 25.202. Accordingly, changes in the out-of-band emissions rules are necessary to protect adjacent TDMA/FDMA systems.

2.2 Downlink Interference Analysis

In addition to the interference into MSS satellite uplinks, MSS uplink transmitters can interfere with downlink services in adjacent bands when a subscriber unit transmits in the vicinity of a downlink receiver. This interference is of particular concern when the victim downlink receiver is operating as part of an AMSS(R) service operating in the 1610 to 1626.5 MHz band. Uplink MSS out-of-band interference may also impair the observations at radio astronomy sites. Finally, interference of this type also can severely degrade the service of the proposed TDMA/FDMA MSS downlink in this band. The level of interference depends on the out-of-band emissions levels of the CDMA mobile transmitter along with the range and propagation factors between the CDMA mobile transmitter and the TDMA/FDMA receiver.

Since a CDMA signal is very wideband compared to an TDMA/FDMA signal, the CDMA interference has the effect of raising the noise floor of the TDMA/FDMA unit receiver. The interference budget for the TDMA/FDMA system includes interference from both internal sources, such as adjacent TDMA/FDMA channel interference and channel reuse, and from external sources which would include the CDMA interference. As long as the combined internal and external interference remains at or below the amount budgeted for external systems, the TDMA/FDMA receiver noise floor will be raised less than 1 dB, and the performance impact will be negligible.

The interference PSD received by an TDMA/FDMA unit from a CDMA mobile transmitter is given by :

$$Io = \frac{PoG_r\lambda^2}{(4\pi R)^2 L_i L_c}$$ [2]

Where :

> Po = The effective radiated PSD in the direction of the TDMA/FDMA unit
>
> G_r = The TDMA/FDMA unit antenna gain in the direction of the CDMA mobile unit.
>
> λ = the RF wavelength
>
> L_i = the out-of-band isolation of the CDMA mobile transmitter
>
> L_c = the excess propagation loss between the CDMA mobile unit and the TDMA/FDMA unit
>
> R = the range between the CDMA mobile unit and the TDMA/FDMA unit

The significant parameters assumed for the downlink analysis are given in Table 3. The TDMA/FDMA unit values are based on the current TDMA/FDMA system design. The CDMA mobile unit values are based on typical parameters provided in the CDMA system filings with the FCC.

The relative height of the CDMA mobile unit antenna and the TDMA/FDMA unit antenna is an important parameter in this interference analysis. Typically, when the CDMA and TDMA/FDMA units are portable or mobile radios, their antenna's will be about 2 m above the local ground. Under some conditions, however, the two units will be at considerably different heights due to local terrain or because one or the other units is used in a multi-story building. Under this condition, the line-of-sight of the elevated unit may be greatly extended, and hence its propagation paths will be considerably enhanced. This situation may be considerably worse if the TDMA/FDMA unit is providing AMSS(R) service when its antenna may be much higher than the CDMA mobile unit and the propagation path will often be unobstructed. The propagation models used in this analysis account for this factor. The analysis assumes a 2 m CDMA mobile unit antenna height and a 2 m antenna height for mobile TDMA/FDMA units. When the TDMA/FDMA unit was operated as an AMSS(R) receiver, a 1 km height was assumed as a reasonable worst case for small separation between the CDMA mobile unit and the TDMA/FDMA AMSS(R) unit.

If the TDMA/FDMA unit is operating as part of an AMSS(R) service, the elevation angle between the CDMA mobile unit and the TDMA/FDMA unit will typically be large, as will the separation between them. Under these conditions, the propagation path will generally be clear line of sight.

Propagation under these conditions will tend to follow the free space model, but under some circumstances, such as an over water flight with the CDMA mobile in line-of-sight near the shore, the plane earth propagation model would be more appropriate. This model combines the free space path with a specular reflected path[1]. The propagation losses for the free space model and the plane earth model are compared in Table 4.

TABLE 3
DOWNLINK INTERFERENCE ANALYSIS PARAMETERS

PARAMETER	VALUE
CDMA MOBILE UNIT:	
EIRP	0.05 dBWi
Channel Bandwidth	1.25 MHz
Peak Effective Radiated PSD (Po)	-24.9 dBWi/4 kHz
FDMA Unit:	
Thermal Noise Floor w/ Cold Sky (No)	-205 dBW/Hz
Internal System Interference (Io)	-216.7 dBW/Hz
Noise Bandwidth	25 kHz

When an aircraft with a TDMA/FDMA AMSS(R) receiver approaches or leaves an airport, or when a TDMA/FDMA AMSS(R) receiver is at an air traffic control center , the propagation channel for the downlink interference between to mobile units is similar to the propagation channels encountered in terrestrial mobile communications. These conditions are also encountered when both the CDMA unit and the TDMA/FDMA unit are mobile units. Terrestrial propagation channels generally have excess propagation loss due to multipath and obstructions. This excess loss varies significantly as a function of the propagation environment and it is therefore difficult to characterize. As a result, a number of propagation models have been developed based on theoretical considerations and empirical data[1,2]. This analysis used several of these models from reference [1] and [2] in order to cover various conditions and derive reasonable performance bounds. The path loss derived from these models is shown in Table 5. The range of applicability of the various models is indicated by the range of table entries.

The out-of-band emissions levels of the CDMA mobile unit (represented by L_i in equation [2]) will vary depending on the relationship of the TDMA/FDMA channel frequency to the CDMA channel frequency. In general, a larger frequency separation will result in a larger isolation. In

[1] Lee, W.C.Y. ,Mobile Communications Design Fundamentals , Chapter 2, Wiley and Sons, 2nd Edition, 1993
[2]Parsons, J,D., The Mobile Radio Propagation Channel, Chapters 2 -4, Wiley and Sons, 1992

addition, when the CDMA system is channelized, the CDMA designers will be motivated to provide as much out-of-band isolation as possible to minimize their system internal interference problems.[3]

TABLE 4
CLEAR LINE-OF-SIGHT PROPAGATION LOSS

CDMA antenna height (m)	2	
FDMA antenna height (m)	1000	
Frequency (MHz)	1620.00	
RANGE (m)	Free Space	Plane Earth
1	-36.69	-38.66
3	-46.23	-40.88
5	-50.67	-50.33
10	-56.69	-62.05
30	-66.23	-61.05
50	-70.67	-68.64
100	-76.69	-71.18
300	-86.23	-80.27
500	-90.67	-84.67
1000	-96.69	-93.39
1500	-100.21	-94.19
3000	-106.23	-103.32
5000	-110.67	-105.68
10000	-116.69	-116.35
30000	-126.23	-122.58
50000	-130.67	-124.83

The downlink interference analysis was conducted with three levels of out-of-band isolation, 20 dB , 40 dB and 55 dB, which correspond to PSD levels of -45 dBW/3 kHz, -60 dBW/3 kHz and -75 dBW/3 kHz respectively. These levels were selected because they bound the expected out-of-band emissions levels based on existing terrestrial CDMA cellular mobile transmitter designs. It is expected that similar performance can be obtained in MSS CDMA mobile transmitters.

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[3] Internal interference in a CDMA system results in lost capacity and thus, lost revenue opportunities.

TABLE 5
PROPAGATION LOSS FOR VARIOUS EMPIRICAL TERRESTRIAL PROPAGATION MODELS

RANGE (m)	Lee Open Area (Area-to-Area Model @ 90% Confidence)	Lee Subburban (Area-to-Area Model @ 90% Confidence)	Lee Newark (Area-to-Area Model @ 90% Confidence)	Lee Tokyo(Area-to-Area Model @ 90% Confidence)
1				
3				
5				
10				
30				
50				
100				
300				
500				
1000				
1500	-115.30	-128.16	-137.78	-151.78
3000	-128.40	-139.72	-148.86	-162.86
5000	-138.05	-148.24	-157.02	-171.02
10000	-151.14	-159.80	-168.10	-182.10
30000	-171.90	-178.12	-185.66	-199.66
50000	-181.55	-186.64	-193.82	-207.82

RANGE (m)	Egli Plane Earth Model (1000 MHz Model @ 90% Confidence)	Okamura/Hata Suburban (Median)	Lee MicroCell	Witteker Ottawa Data
1				
3				
5				
10				
30			-91.38	-91.23
50			-96.15	-95.67
100		-93.36	-101.04	-101.69
300		-113.84	-107.72	-111.23
500		-123.36	-115.67	-115.67
1000	-128.11	-136.28	-126.66	-121.69
1500	-135.15	-143.84	-133.09	
3000	-147.19	-156.77		
5000	-156.07	-166.29		
10000	-168.11	-179.21		
30000	-187.19	-199.70		
50000	-196.07	-209.22		

Virtually all MSS and satellite AMSS(R) channels will encounter some degree of fading due to multi-path and/or blockage, so it is not practical to operate a system of this kind without some fade margin. TDMA/FDMA MSS propagation data has shown that a fade margin of 10 dB will provide satisfactory voice quality under many terrestrial link conditions, even though it will not provide adequate quality in the most difficult channels such as operating an TDMA/FDMA unit in a vehicle. It was therefore, decided to use a 10 dB fade margin as a rule-of-thumb for a marginally useful TDMA/FDMA mobile unit channel. TDMA/FDMA AMSS(R) systems operating while airborne will encounter less severe fading than mobile units. A link fade margin of about 5 dB is adequate for such AMS(R)S TDMA/FDMA channels. The CDMA interference is negligible when the fade margin is 15.5 dB or more.

The interference impact on the TDMA/FDMA downlink channel was analyzed as a function of the range between the CDMA mobile unit and the TDMA/FDMA unit. The results are provided in the following tables for the various propagation models. Each model is applied three times, once for each value of out-of-band emissions. The entries in the tables are the available fade margin under the indicated interference condition.

Table 6 shows the link fade margin under the clear line-of-sight conditions associated with AMSS(R) service when the aircraft is at a moderate to high altitude. Under these conditions, fading between the TDMA/FDMA receiver and the satellite will be moderate. As shown in the table, when the CDMA out-of-band isolation is 20 dB which corresponds to -45 dBW/3kHz, the range between the CDMA mobile unit and the AMSS(R) TDMA/FDMA receiver must be about 10 km if propagation conditions approximate clear line-of-sight, and about 1.5 km when a strong specular reflection cancels part of the interference from a CDMA mobile transmitter. When the CDMA transmitter out-of-band emissions is reduced to -60 dBW/3 kHz (40 dB isolation), the range drops to between 500 m and 1000 m. Finally, at -75 dBW/3 kHz (55 dB isolation) the minimum range for AMSS(R) TDMA/FDMA operation is about 300 m. Since clear-line-of sight operation requires reasonably high altitudes, the 500 m to 1000 m range appears to be adequate for these propagation channels.

As Table 5 indicated, most of the available terrestrial propagation models have not been shown to be valid at ranges less than about 1500 m. Ranges much lower than this are of interest in studying the interference by a CDMA mobile transmitter into a TDMA/FDMA mobile receiver or AMSS(R) ground receiver. Because there is no general industry agreement on a very short range terrestrial propagation loss model, this analysis used all three short range models from Table 5 to bound the performance. The TDMA/FDMA link fade margin for these three models is given in Tables 7 and 8 below.

TABLE 6
TDMA/FDMA AMSS(R) LINK FADE MARGIN WITH CDMA INTERFERENCE UNDER CLEAR LINE OF SIGHT CONDITIONS

Out-of-Band Isolation	20	40	55	20	40	55
Propagation Loss Model	Free Space	Free Space	Free Space	Plane Earth	Plane Earth	Plane Earth
Range (m)	Remaining Downlink Fade Margin	Remaining Downlink Fade Margin	Remaining Downlink Fade Margin	Remaining Downlink Fade Margin	Remaining Downlink Fade Margin	Remaining Downlink Fade Margin
1	-71.26	-51.26	-36.26	-77.26	-57.26	-42.26
3	-61.72	-41.72	-26.72	-67.74	-47.74	-32.74
5	-57.28	-37.28	-22.28	-61.55	-41.55	-26.55
10	-51.26	-31.26	-16.27	-56.25	-36.25	-21.25
30	-41.72	-21.72	-6.74	-47.63	-27.63	-12.64
50	-37.28	-17.29	-2.35	-35.31	-15.31	-0.42
100	-31.26	-11.27	3.48	-37.10	-17.10	-2.17
300	-21.72	-1.80	11.35	-20.61	-0.70	12.03
500	-17.29	2.51	13.64	-11.93	7.40	15.05
1000	-11.27	7.96	15.15	-0.08	14.41	15.74
1500	-7.76	10.67	15.50	6.52	15.48	15.79
3000	-1.80	13.85	15.72	14.13	15.78	15.80
5000	2.51	14.99	15.77	15.54	15.79	15.80
10000	7.96	15.58	15.79	15.78	15.80	15.80
30000	13.85	15.77	15.80	15.80	15.80	15.80
50000	14.99	15.79	15.80	15.80	15.80	15.80

Analysis based on the short range propagation models in Tables 7 and 8 predicts that the interference will become tolerable for many AMSS(R) ground receivers and TDMA/FDMA mobile receivers at a range of about 100 m and should be negligible by approximately 500 m, provided that a CDMA mobile transmitter provides out-of-band isolation in the range of 40 dB (-60 dBW/3kHz) for most TDMA/FDMA channels. Further, when the isolation increases to 55 dB (-75 dBW/3 kHz) the TDMA/FDMA link is nearly unaffected by CDMA systems as close as 30 to 50 m according to the two short range models that extend below 100 m.

TABLE 7
TDMA/FDMA LINK FADE MARGIN WITH CDMA INTERFERENCE BASED ON THE OKOMURA/HATA PROPAGATION LOSS MODEL

Isolation	20	40	55
Propagation Loss Model	Okomura/ Hata Suburban	Okomura/ Hata Suburban	Okomura/ Hata Suburban
Range (m)	Remaining Downlink Fade Margin	Remaining Downlink Fade Margin	Remaining Downlink Fade Margin
100	-14.60	5.03	14.51
300	5.47	15.39	15.78
500	12.59	15.75	15.79
1000	15.56	15.79	15.80
1500	15.75	15.80	15.80
3000	15.79	15.80	15.80
5000	15.80	15.80	15.80
10000	15.80	15.80	15.80
30000	15.80	15.80	15.80
50000	15.80	15.80	15.80

TABLE 8
TDMA/FDMA LINK FADE MARGIN WITH CDMA INTERFERENCE BASED ON MICROCELL PROPAGATION LOSS MODELS

Isolation	20	40	55	20	40	55
Propagation Loss Model	Lee MicroCell	Lee MicroCell	Lee MicroCell	Witteker Ottawa Data	Witteker Ottawa Data	Witteker Ottawa Data
Range (m)	Remaining Downlink Fade Margin	Remaining Downlink Fade Margin	Remaining Downlink Fade Margin	Remaining Downlink Fade Margin	Remaining Downlink Fade Margin	Remaining Downlink Fade Margin
30	-16.57	3.19	13.91	-16.57	3.19	13.91
50	-11.81	7.50	15.07	-11.81	7.50	15.07
100	-6.94	11.22	15.55	-6.94	11.22	15.55
300	-0.34	14.33	15.74	-0.34	14.33	15.74
500	7.09	15.53	15.79	7.09	15.53	15.79
1000	14.00	15.77	15.80	14.00	15.77	15.80
1500	15.32	15.79	15.80			

3. A PROPOSED MASK FOR THE MSS UPLINK BANDS

The out-of-band emissions interference problem was recognized during the negotiated rule making in Docket No. CC 92-166. Indeed, consensus was reached that a change in Rule 25.202 would be necessary to protect adequately systems in adjacent bands. There was some concern, however, about the

equity of the various proposals for changes to these rules because of the widely different bandwidths of the uplink signals. Rules based on relative power spectral density, for example, tend to favor TDMA/FDMA systems over CDMA systems because the in-band power spectral density of the CDMA systems is already quite low. Traditional spectral mask rules based on offset frequencies relative to the authorized bandwidth of the transmitter, on the other hand, tend to favor CDMA systems because they have much larger authorized bandwidths and therefore are permitted much wider out-of-band emissions plateaus. The proposed rules in this paper avoid these inequities by establishing fixed out-of-band power limits at fixed frequency offsets from the band edge or the boundary between the MSS band segments. Thus, each MSS uplink transmitter is allowed the same out-of-band emissions levels regardless of the technology.

Figure 4 illustrates the proposed out-of-band emission rules for all MSS uplink transmitters :

Frequency Separation	Power Spectral Density
$\Delta f < 125$ kHz	-45 dBW/3 kHz
125 kHz $\leq \Delta f < 1.25$ MHz	-60 dBW/3 kHz
$\Delta f \geq 1.25$ MHz	-70 dBW/3 kHz

Where Δf is the frequency separation from the edge of the authorized band.

The standard mask given above applies for transmitters with a maximum antenna gain of 0 dBi at 0 degrees local elevation and 3 dBi at other elevation angles when the transmitter is operated in its nominal configuration and attitude. Transmitters whose antenna gain exceeds these limits should comply with the following modified mask.

Frequency Separation	Power Spectral Density
$\Delta f < 125$ kHz	-45 dBW/3 kHz - [10log(G)-3 dB]
125 kHz $\leq \Delta f < 1.25$ MHz	-60 dBW/3 kHz - [10log(G)-3 dB]
$\Delta f \geq 1.25$ MHz	-70 dBW/3 kHz - [10log(G)-3 dB]

Where G is the maximum antenna gain at any elevation angle in dBi.

The out-of-band emissions rules proposed as changes to Section 25.202 were selected primarily as a consequence of the downlink interference analysis. When the analysis levels were compared with the practical amplifier performance, the -45 dBW/3kHz and -60 dBW/3kHz limits were readily achieved at the required offset frequencies, but the -75 dBW/3kHz level was

not achieved until the frequency offset was significantly larger than 1.25 MHz required in the proposed mask. It was noted, however, that the TDMA/FDMA downlink performance with -75 dBW/3kHz exceeded the condition for a marginally acceptable link. Thus, the proposed final out-of-band emissions level was adjusted to -70 dBW/3kHz. As a result of this change, these limits are practical for both CDMA transmitters and TDMA/FDMA transmitters and have been shown by the above analysis to provide adequate protection for both the AMSS(R) service and MSS services in the 1610 MHz to 1626.5 MHz band. In addition, while these out-of-band limits do not, in themselves, avoid interference to the Radio Astronomy Service, they would greatly reduce the extent of the exclusion zone that must be established around a radio astronomy observatory to avoid interference from transmitters operating in CDMA channels above the RAS band.
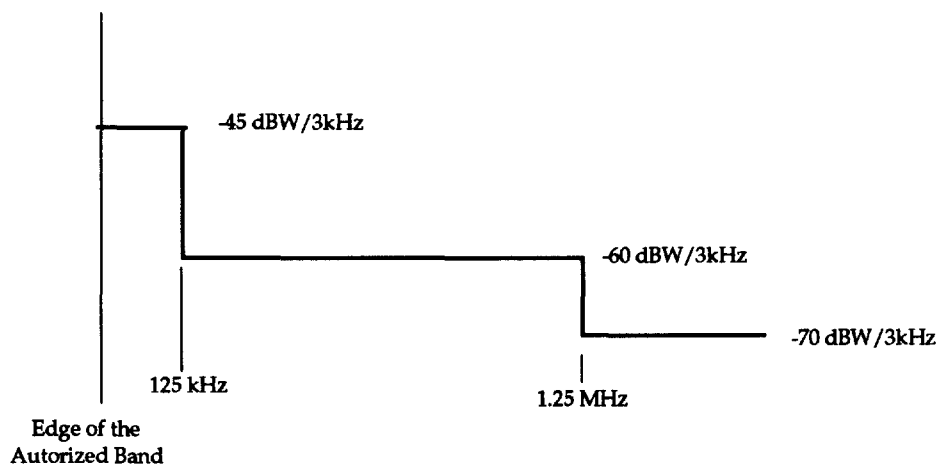

Figure 4. Proposed Out-Of-Band Power Spectral Density Limits for the 1610 - 1626.5 MHz Band

4.   CONCLUSION

The existing earth station out-of-band emission limits contained in Rule 25.202 are inadequate to protect a TDMA/FDMA system from harmful interference caused by CDMA systems in the adjacent band operating in compliance with those limits. New out-of-band emissions limits are required to provide adequate protection. The proposed rules are compatible with power amplifier technology developed for TDMA/FDMA and CDMA mobile transmitters. The proposed rules avoid favorable treatment of one technology over the other by setting fixed power spectral density limits at fixed frequency offsets from the authorized band.

Radio Astronomy Protection Criterion

1. Summary

The proposed protection criterion for the Radio Astronomy Service (RAS) in the 1610.6 to 1613.8 MHz band is based on a constant interfering source originating from a stationary (relative to the Earth) transmitter site. The criterion is formulated to limit the degradation of the RA receiver to result in 10% loss of data (the approximate added observing time needed for equivalent sensitivity). This proposed reference interference level must be reexamined in light of the differences between the types of interference. The final criteria for acceptability of interference should be based on the ability of the Radio Astronomy Service to make the desired observations and the requirements of the proposed MSS system.

The following sections contain an outline of the history of the current RAS protection frequencies. The assumptions that apply to the interference equation derived in CCIR Report 224, which is presented in a concise format, are reviewed. The discussion points out why the assumptions do not clearly apply to the case of a non-constant, moving interference source, such as a LEO MSS satellite. Sharing mechanisms are suggested followed by comments on rational adjustments to the proposed rule. There is also a short discussion of the significant and costly efforts that have already been made by the TDMA/FDMA MSS System applicant to reduce the interference from the proposed MSS system downlink in the 1616 to 1626.5 MHz band.

2. A Protection Criterion - CCIR Report 224

2.1 Frequencies for Protection

In the late 1940's and the early 1950's radio astronomers recognized the need for protection of the Radio Astronomy Service from outside interference. The use of the radio frequency (RF) spectrum was increasing rapidly. The increase in use of the spectrum resulted in the reduction of open frequency bands which were available for Radio Astronomy observations. The RA community, the FCC and the CCIR began a process of defining frequencies and standards for the protection of Radio Astronomy.

The majority of observations at the time were made using single radio astronomy antennas. The observations were made (as many are today) primarily by pointing the large Radio Astronomy dishes at distant celestial objects and either measuring the continuum power level (a constant, full spectrum emission characteristic) or measuring the power at given spectral lines. The continuum measurements can take place at any frequency across the spectrum.

The spectral lines that are observed are related to molecular resonances and exist at particular frequencies. The objects being observed are generally at interstellar and intergalactic distances and have high velocities relative to the Earth. These velocities (primarily away from the Earth due to the expanding universe) result in Doppler shifts of the observed frequencies. The frequencies over which these molecular resonances are observed can cover a wide bandwidth. Most of the

observed spectral lines will be red shifted (lower in frequency) and fairly close to the original spectral line frequency. Very large red shifts are possible to observe.

Although it is desirable from a scientific viewpoint to be able to make measurements across the entire band, suggested continuum observation bands are restricted to a small fraction of the RF band so that communications services are not excessively constrained. Spectral line observation bandwidths are also restricted to a smaller bandwidth than the full possible Doppler shift range. This allows the radio broadcast service, the military communications services, the telecommunications services, and other services to exist. These communications services provide critical information services as well as timely emergency aid services.

Many of the suggested RA observation bands are now recognized by both the FCC and by the CCIR and are reflected in the relevant spectrum allocation tables and rules. These rules also contain recommended protection criteria.

2.2 Protection Criteria

The current suggested criterion for protection of the Radio Astronomy service in the 1610.6 to 1613.8 MHz band is based on CCIR Report 224. The first version of this report was released in 1963 and has been modified a number of times. The basic protection criterion that is derived in this report is based on continuum observations and on spectral line observations using single RA antennas. The primary criterion used for derivation of suggested coordination levels is a limit of a 10% degradation of Radio Astronomy measurements. The dominant interference mode considered (when first derived) was the interference from a single point terrestrial source into a Radio Astronomy receiver. The interference source was not moving; more important, it entered the RA receiver by means of an antenna sidelobe.

The equation derived in CCIR Report 224 for a reference interference level is

$$S_H = 0.1 \frac{4\pi}{g\lambda^2} \frac{k(T_A + T_R)}{\sqrt{2\Delta f \Delta t}} \qquad [\text{W} / \text{m}^2 - Hz]$$

Where: S_H is the reference harmful interference level,
"0.1" represents a 10% degradation,
g is the off axis gain of the Radio Astronomy Antenna in the direction of the interfering source [ratio],
λ is the wavelength of the RF energy [m],
k is Boltzmann constant,
T_A is the antenna noise temperature due to cosmic background noise coming from all directions (including the sidelobes) [K],
T_R is the antenna noise temperature due to the receiver noise [K],
Δf is the reference observation bandwidth [Hz],
and Δt is the observation time [seconds].

The parameters of this equation are assumed to characterize a given situation. The equation does not apply to the interference tolerance of antennas being used for interferometry observations. These are performed by correlating the measurements

made via several antennas. This type of measurement is the primary function of phased arrays such as the VLBA, which is scattered throughout the USA; the VLA, in New Mexico; and many other sites. These observatories are much more tolerant of interference and also represent the state of the art in Radio Astronomy observations. The proposed rule reflects this greater tolerance to interference for the VLBA sites.

The equation assumes that the interfering source is on continuously so that the service to the site is degraded by 10%. For spectral line observations the report estimates the relevant frequency bandwidth as

$$\Delta f = f(3000[m/s]/c)$$

Where   f is the frequency of interest [Hz],
                     c is the speed of light [m/s].

The parameters assumed in Report 224 and corresponding to the spectral line at 1612.24 MHz are: g = 1.0 (0 dBi), = 0.18 m, T_A = 10 K, T_R = 20 K, f = 16131 Hz, and t = 2000 s. This corresponds to a point source constantly radiating energy into a 0 dBi sidelobe of a radio astronomy antenna. This also assumes that the cosmic background noise is the lowest possible value (T_A = 10 K). The reference interference level corresponding to these assumptions is -237 dBW/m²/Hz.

For other conditions other parameters apply. For instance, during the daytime the RF flux from even the "quiet" (with a spectral density of about -202 dBW/m²/Hz near the peak of the 11-year sunspot cycle to -204 dBW/m²/Hz at the trough of that cycle) increases the effective background noise temperature substantially for any radio telescope aimed near it--the actual degradation depends on a number of construction parameters of the telescope, but the degradation for lines of sight near the sun is always considerable. It has been noted in the past that the solar radiation power is known (it varies over time, but can be measured) and can be removed. This can be done to adjust the continuum power levels measured, but it cannot increase the sensitivity of the receiver. The equation derived by the Radio Astronomers (shown above) still applies. The 1610.6 to 1613.8 MHz RAS band is not reserved for measuring the continuum radiation, but rather for measuring the OH spectral lines. When measuring the spectral lines the absolute level can be calibrated by subtracting the local, flat noise floor (and the apparent spectral warping of the noise floor due to the instrument-unique, frequency dependent feed-reflector standing-wave effects) from the spectral line level. This removes the noise from the sun or one of the many other "hot" RF celestial objects, the noise from the RA receiver, and the interference -- provided that the interference is spectrally flat. The proposed MSS system downlink has been redesigned so that the expected interference that may occur above a defined limit is spectrally flat (see discussion below).

If the interfering source varies in power level over the 2000 second period (corresponding to the 2000 second Radio Astronomy observation integration period) the power must be averaged. This can change how the reference interference level is perceived.

In CCIR Report 224 the sidelobe gain level of the RA antenna is assumed to be 0 dBi. This estimate for sidelobe gain is based on an old CCIR recommendation for